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Inhalt

Two decades of dendrochronology in the pile dwellings of the Ljubljansko barje, Slovenia

Katarina Čufar, Anton Velušček and Bernd Kromer

Introduction

Prehistoric pile dwellings at the Ljubljansko barje (germ. das Laibacher Moor) in Slovenia were first discovered in 1875. Up to now over 40 known pile dwellings have been recorded with an undetermined exact period of existence (e.g. Velušček 2004a). In 1995, archeological excavations were started for systematical acquisition and research of waterlogged wood, mainly from the piles on which the dwellings were built. The objective of this article is to give an overview of the achievements and unsolved questions of nearly two decades of wood research supported by dendrochronology and radiocarbon analyses.

Dating of the settlements

Between 1995 and 2013 we have investigated the wood of 15 pile dwellings and collected 8,432 samples. At some locations excavations have been repeated several times over the years and they still continue (Tab. 1).

At each of the sites we collected samples of all wooden items and performed wood identification (Tab. 2). The most frequent species were ash (*Fraxinus excelsior*), oak (*Quercus robur* and *Quercus petraea*) and alder (*Alnus glutinosa*) followed by maple (*Acer* sp.), willow (*Salix* sp.) and poplar (*Populus* sp.). Hazel (*Corylus avellana*), hornbeam (*Carpinus betulus*), beech (*Fagus sylvatica*), silver fir (*Abies alba*) and elm (*Ulmus* sp.) were found in smaller amounts (Tab. 2). The selection of wood species, together with other data, helped us to obtain information on past environment and vegetation, wood acquisition (both from the floodplain and the more distant forests on its outskirts), the development of the settlements and plant economy (e.g. Tolar et al. 2011).
We counted tree-rings on all samples. Oak, ash and beech samples containing more than 45 rings were selected for measurement of tree-ring widths. For each sampling and site, tree-ring series of analysed samples were cross-dated and joined in floating chronologies.
We constructed 11 oak site chronologies. These chronologies were the most relevant, since oak is the most frequent and important wood in European archaeology, one for

No.	Site	Code	Year of Archaeological Research	No. of Wood Samples
1	Resnikov prekop	RP	2002	34
2	Hočevarica	HOC	1995, 1998	361
3	Strojanova voda	SV	2012	351
4	Maharski prekop	MP	2005	234
5	Črešnja pri Bistri	CR	2003	124
6	Spodnje Mostišče	SM1+2	1996, 1997	690
7	Stare Gmajne	SG	2002, 2004, 2006, 2007	932
8	Veliki Otavnik	VO	2006	30
9	Blatna Brezovica	BB	2003	170
10	Parte-Iščica	PI	1997, 1998	1265
11	Črni graben	CG	2010	50
12	Parte	PAR	1996	242
13	Založnica	ZAL	1995, 1999, 2001, 2009	1465
14	Dušanovo	DU	2010	32
15	Špica	SPC	2010, 2011	2452
Total				**8,432**

Tab. 1 Pile dwelling settlements at the Ljubljansko barje, years of excavation and numbers of analysed wood samples.

Site	*Fraxinus*	*Quercus*	*Alnus*	*Acer*	*Salix*	*Populus*	*Corylus*	*Carpinus*	*Fagus*	*Abies*	*Ulmus*	Others
Resnikov prekop	24		53	3								21
Strojanova voda	62	16	10	2	2	2		1		5		
Hočevarica	51	37	7	3		0	2					
Maharski prekop	30	35	12	10	2	3	4	1	2			1
Črešnja pri Bistri	20	49	22	2	1	3	3					
Spodnje mostišče	22	59	7	11				1				
Stare gmajne	44	36	3	3	2	5	1	1	3			1
Veliki Otavnik	20	57	7		7	10						
Blatna Brezovica	32	51	2	9	1	1	2		2			
Parte-Iščica	70	2	9	3	1	3	2	1	7	1	1	
Črni graben	100											
Parte	62	33	4	1								
Založnica	54	29		2	6	2	3	1	2			1
Dušanovo	63				37							
Špica	60	21	2	3	3	0	1	3	4	1		2

Tab. 2 Percentages of wood genera in pile dwellings. The predominating genus is shaded dark grey. Genera: Abies – fir, Acer – maple, Alnus – alder, Corylus – hasel, Carpinus – hornbeam, Fagus –beech, Fraxinus – ash, Populus – poplar, Quercus – oak, Salix – willow, Ulmus – elm, Others – other species or wood not identified due to poor preservation.

which a network of long chronologies exists (Haneca et al. 2009). At most of the sites we also constructed chronologies of ash, the species most frequently used for piles (Tab. 2).

At the beginning of the investigation we took at least one representative wood sample for radiocarbon dating, performed by one of our team (Bernd Kromer) at the Institute of Environmental Physics of the Heidelberg Academy of Sciences. As the number of prehistoric chronologies gradually increased we could often date a newly built chronology by means of dendrochronological cross-dating with other chronologies.

The systematic work helped us to gradually build a network of partly overlapping chronologies absolutely dated with the help of 14C dates calibrated with the wiggle-matching procedure (Čufar et al. 2010). Time spans and end dates of the chronologies are shown in Figure 1.

Table 1 and Figure 1 show the end dates of the tree-ring chronologies of the investigated dwellings. The oldest site is Resnikov prekop (~4600 BC) for which we could not construct a chronology. This site is presented in detail in Velušček 2006.

The period from 3744–3302 BC is covered by 6 overlapping oak chronologies, which could be cross-dated. Numerous ^{14}C dates and wiggle-matching helped us to date them with a precision of ±10 years (Čufar et al. 2010). For this period we also constructed several ash chronologies which helped us to better reconstruct building activities on the sites.

The period from 3285–3108 BC is covered by two overlapping chronologies dated with a precision of ±14 years (Čufar et al. 2010). The end date of the chronology of Blatna Brezovica is only estimated.

Ash was the predominant tree species on the 3rd millennium BC sites (Tab. 2). For Parte Iščica we constructed three chronologies, two of ash and one of beech. They are short and could not be cross-dated. Their dating is based on radiocarbon dates (one sample per chronology).

In the 3rd millenium BC, the period between 2659 and 2417 BC is covered by the oak chronology of Založnica, dated with a precision of ±18 years. It enabled us to date ash chronologies from Založnica, Črni graben and Parte, and oak chronology from Parte. The Parte and Založnica sites mark the end of the Copper Age at the Ljubljansko barje (Velušček/Čufar 2003; Velušček et al. 2011). Tree-ring chronologies for the Špica site, where wood investigations are still ongoing, are yet to be constructed. Based on archaeological artefacts and cross-dating of a few individual tree-ring series of this site, we suppose that it might have existed in the 26/25th century BC.

The cultural arrangement of the settlements and connections with other contemporaneous settlements and cultures in Central and SE Europe is discussed in Velušček/Čufar 2010.

In addition to the construction of chronologies, felling dates of individual trees helped us to determine several building phases on most of the sites. Building activities or repairs were inferred from large numbers of trees felled in the same year or within a period of a few years. The years of building activities are discussed in publications on individual sites (e.g. Velušček/Čufar 2003; Čufar et al. 2009; 2010). These data also indicate possible settlement gaps at the Ljubljansko barje, for instance between 3332±10 and 3160±14 cal BC which could be due to the lack of preserved archaeological wood or, more likely, due to a hiatus in the occupation of the Ljubljansko barje (Čufar et al. 2010). It is possible that the settlement gaps in the 4th millennium BC on the Ljubljansko barje do not match the settlement gaps north of the Alps (Magny/Haas 2004).

Apart from the Špica site (where wood investigations are still ongoing), the investigated sites are located in the southern part of the Ljubljansko barje. In all the researched periods we recorded contemporaneous building activities at ca. 10 km distant sites in the SW and SE part of the Ljubljansko barje. Such pairs of contemporaneous dwellings are, for instance, Strojanova voda-Hočevarica, Spodnje mostišče-Stare gmajne old, Parte-Založnica (Fig. 2).

Stare gmajne in the SE part of Ljubljansko Barje, located where the floodplain abruptly ends at the edge of the Dinaric Karst, is one of the most extensively investigated sites. It

is possible that, like today, the nearby edge of the Dinaric Karst was covered with large forests. Our archaeobotanical data, together with wood investigations, helped us to reconstruct the past environment, the acquisition of wood from the floodplain and from the Dinaric forests, and the nutritional habits of pile dwellers (Tolar et al. 2011; Velušček 2004b; 2009). The more recent settlement at Stare gmajne, which ended around 3109 BC, can be compared with a number of well investigated sites north of the Alps at the time of the prehistoric Alpine Iceman Ötzi (Jacomet 2009).

The most valuable wooden objects also originate from Stare gmajne, such as the approximately 5,150 year old wheel with axle, made of ash and oak wood (Velušček et al. 2009a). Two canoes were also found at Stare gmajne (Velušček et al. 2009b), whereas the oldest bow originates from the older Hočevarica site (Fig. 3).

It is particularly important for the conservation of such objects to know the specific properties of the wood of which they are made. As a rule, the waterlogged wood from the pile dwellings is very poorly preserved (Čufar et al. 2008b).

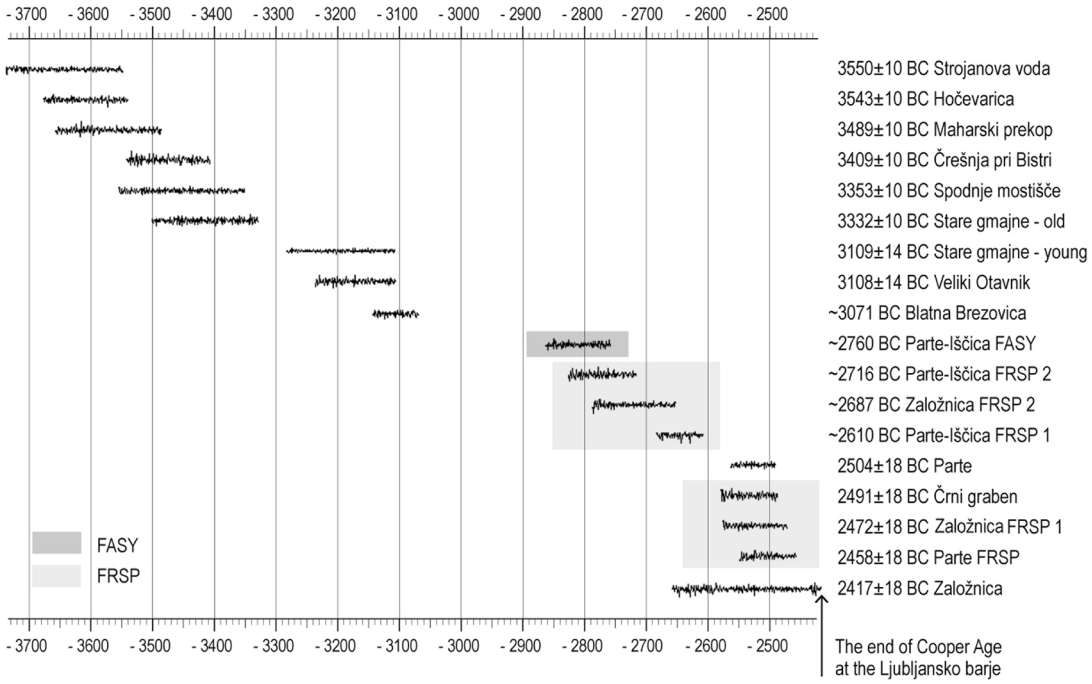

Fig. 1 Dated tree-ring chronologies of pile dwelling sites at the Ljubljansko barje. The unshaded ones are oak chronologies; the shaded ones are chronologies of ash (FRSP) and beech (FASY).

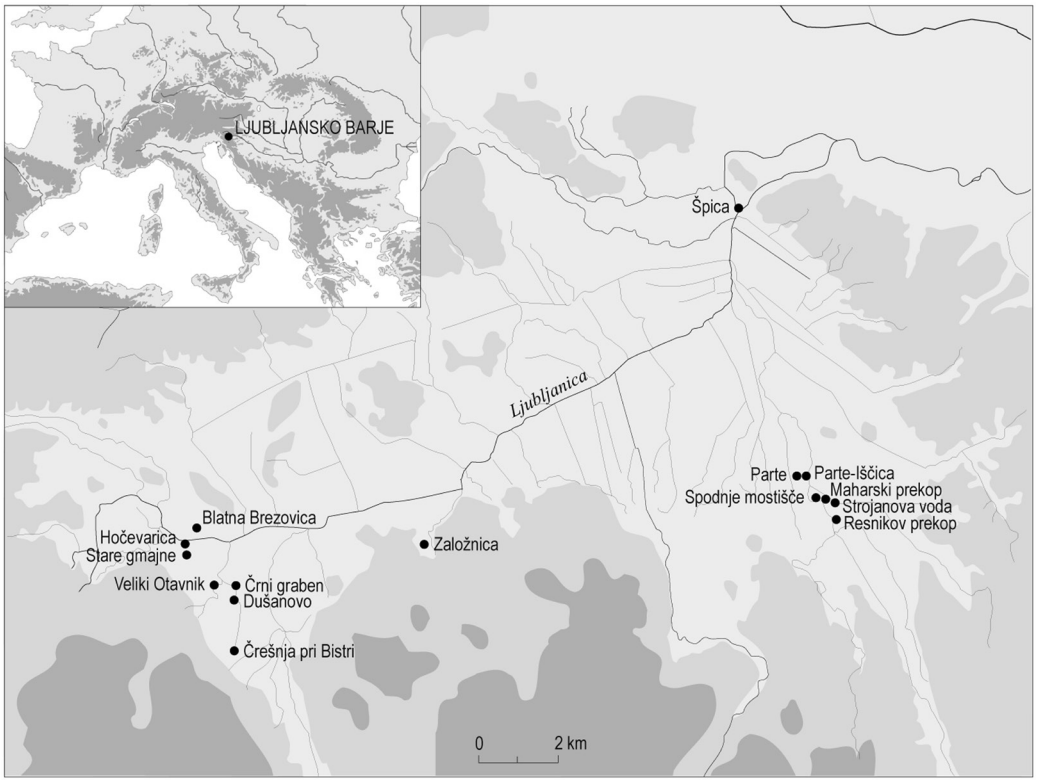

Fig. 2 Location of pile dwellings at Ljubljansko barje dated to the 5th, 4th, and 3rd millennium BC. Drawing: Tamara Korošec, Institute of Archaeology ZRC SAZU.

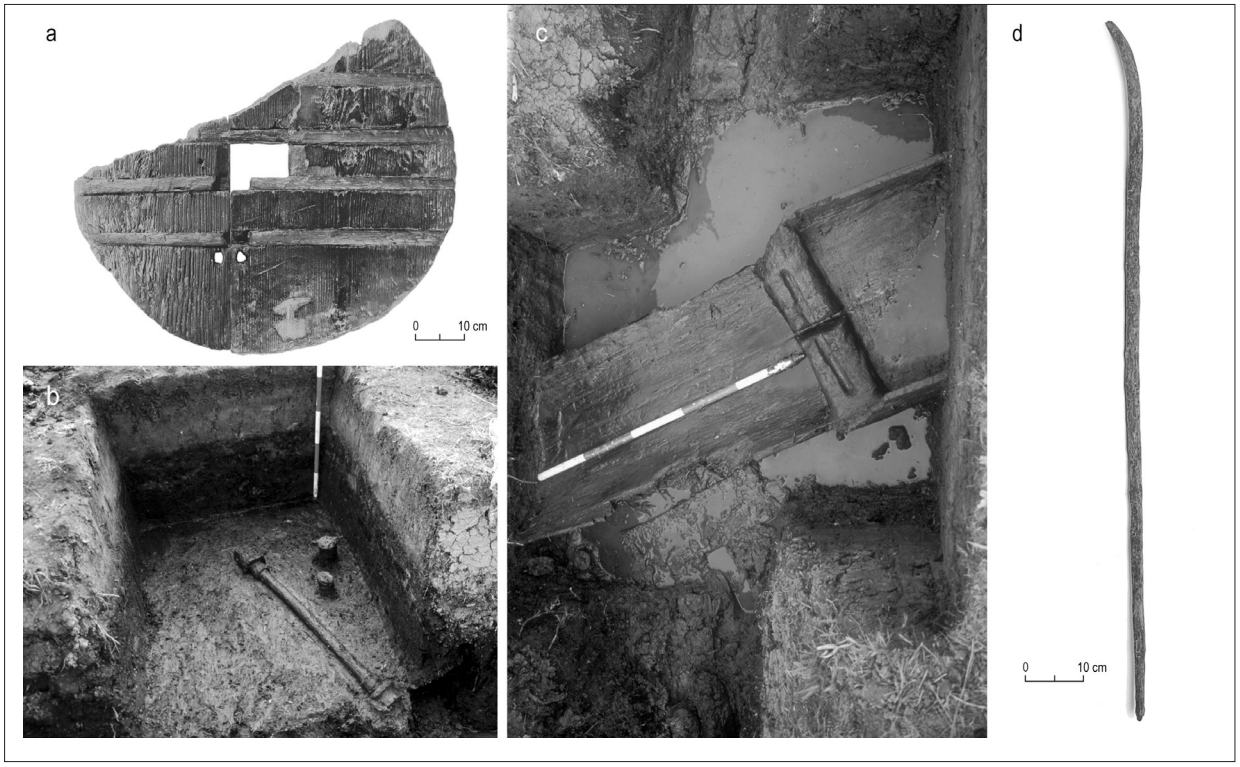

Fig. 3. Wheel (a), axle (b), and dugout (c), over 5,150 years old, found in the drainage ditches on the Stare gmajne site. An approximately 5,600 year old bow (d) found at Hočevarica site. Photos: Institute of Archaeology ZRC SAZU.

Teleconnection

From the beginning of the tree-ring research we attempted to cross-date the Ljubljansko barje chronologies with chronologies from well investigated sites in Germany (e.g. Billamboz 1996; 2006; 2008). To this end, we exchanged the data with Dr. André Billamboz at the Dendrochronological laboratory of the Landesamt für Denkmalpflege, Hemmenhofen, Germany, and with Willy Tegel and Franz Herzig. Unfortunately all attempts at dendrochronological cross-dating of the Ljubljansko barje chronologies failed.

The only successful cross-dating of prehistoric chronologies was that between the oak chronology of Hočevarica (Tab. 1; Fig. 1) and the oak chronology of a structure from the ca. 150 km distant site of Palù di Livenza in Pordenone, NE Italy (Čufar/Martinelli 2004). Unfortunately the chronology of Palù di Livenza is (like the chronologies of Slovenia) only dated by radiocarbon to the first half of the 4th millennium BC.

As already mentioned, oak is considered to be the most important wood in European dendrochronology. The longest continuous tree ring chronology in the world is the oak chronology of South Germany, constructed by the laboratory in Hohenheim. This chronology reaches back to 8480 BC (Friedrich et al. 2004). It is based on over 5,000 samples of living and subfossil trees and timber from constructions uniformly distributed over the entire Holocene (Becker 1993). In the initial phase of construction of this and other long oak chronologies in Europe it was believed that teleconnection of oak was poor, i.e. that tree-ring patterns of oak from distant sites do not match. However, with increasing length and replication even the chronologies of distant sites like Germany and Ireland could be successfully cross-dated (Becker 1993; Baillie 1995). Despite a rich network of long oak chronologies in Europe, long chronologies still do not exist in the regions south of the Alps. In Slovenia, only a ca. 550 years long regional chronology with an end date of 2003 AD could be constructed (Čufar et al. 2008a). Despite continued efforts it has not yet been extended to the past, mainly due to lack of adequate wood from the periods of interest. The well replicated 550 years long oak chronology from Slovenia shows good teleconnection in the radius of ca. 400 km and agrees with the longest South German oak chronology (Čufar et al. 2008a).

In light of these findings, we can expect that cross-dating of our prehistoric chronologies could be successful when their length, replication and quality increases. Unfortunately, we cannot affect the availability of wood from the past.

The impact of wood research on wetland archaeology

Excavations and investigations of wood from the pile dwellings enabled us to date the sites and to obtain information on past forests and environment, as well as human life and the effect of ancient populations on the environment. The selection of wood species for wood working and use of wood showed that ancient people had a rich knowledge of wood properties. They could optimally select, work and use the wood from the immediate vicinity of the settlements or from more distant sites. Wood helped us to date the time of existence and of building activities on the dwellings and to presume major settlement gaps.

Wood research was just a small but essential part of multi-

disciplinary investigations of the wet environments of the Ljubljansko barje. The multidisciplinary approach helped us to reconstruct an integral picture of human life, environment and connections with other sites.

Summary

Systematical excavations and interdisciplinary research have been performed in prehistoric pile dwelling sites of the Ljubljansko barje in Slovenia since 1995. Wood from 16 sites has been collected for wood identification, dendrochronology and radiocarbon dating. Over 8,400 samples of wood, mainly from the piles, have been collected and investigated. Approximately 20 % of the samples were oak (*Quercus* sp.) and ash (*Fraxinus* sp.) with more than 45 tree-rings and were, according to our criteria, appropriate for dendrochronological investigation which enabled us to construct oak and ash tree-ring chronologies for most of the sites. A partial overlap of the chronologies and their ^{14}C dating supported by a wiggle-matching procedure helped us to define their end dates from 3543±10 to 2417±18 cal BC. Evidence of extensive tree felling in the same years helped us to reconstruct building activities and to propose possible settlement gaps on the Ljubljansko barje. Cross-dating with 400 km distant German chronologies for the 4th and 3rd Millennium BC has proven unsuccessful. Wood investigations have revealed settlement patterns, enabled a reconstruction of past environment and human activities on the Ljubljansko barje and provided a new perspective for the absolute chronology of the Copper Age and the Early Bronze Age on the southeastern outskirts of the Alps.

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